West Africa Built Environment Research (WABER) Conference
WABER 2021 Conference, 9-11 August 2021, Accra, Ghana
Proceedings Edited by Laryea, S. and Essah, E.
ISBN 978-0-620-95367-2

AN INNOVATIVE APPROACH FOR THE EVALUATION OF EXPANSION OPTION IN BUILDINGS

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Expansion option (EO) in buildings is more valuable when it is easier to achieve. Creating EO in initial building designs facilitate future expansion. However, this requires additional investment and the future is unknown whether or not the option would ever be exercised. This paper proposes an innovative approach for the evaluation of EO in buildings to avoid under or over-investment. Mathematical equations and algorithms were first developed based on the binomial method (BM) of real options analysis which were then implemented on a computer system. An algorithm was also developed for Monte Carlo simulation (MCS) and integrated with the binomial model. To illustrate its applicability, a real-life project was used to test the model. Sensitivity analysis was conducted to explore the influence of input variables on expansion option value (EOV). The result shows that inflation rate (i), borrowing rate (b), and rental value (Ri) are the most sensitive variables for EOV. An increase in i and Ri by just 5% causes a corresponding increase in EOV by 16.26% and 10.60% respectively. While an increase in b by just 5% causes a corresponding decrease in EOV by 14.61%. However, the least sensitive variables appear to be the discount rate (r) and volatility (δ). An increase in r by 5% causes a decrease in EOV by 6.9% while an increase in δ by 5% causes an increase in option value by 5.85%. Also, the result shows that creating EO in the initial design adds over 10% value to a building. More so, by integrating the BM with the MSC method, EOV increases by 190%. The model builds upon a previously developed model for evaluating building development option (DOV) which was found to have a result accuracy of 80.77%. It was recommended that building investment decision-makers should combine both BM and MCS to obtain more reliable and sustainable results.

Keywords: binomial method, building investment, expansion option, Monte Carlo simulation, sustainable building development

INTRODUCTION

Investment in building projects is often capital intensive with a long investment recovery circle amid multi-dimensional risks and uncertainties. According to Ellingham and Fawcett (2006), for economically sustainable building projects, it is

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necessary to ensure optimal investment – avoiding under or over-investment. Therefore, comprehensive evaluation of building projects is crucial especially in an era of economic downturn. However, despite the existence of whole-life costing (WLC) models, determining the economic benefits of buildings has been a difficult task due to the lack of reliable data and the inherent limitations of the existing WLC models (Tokede, Love & Ahiaga-Dagbui 2018). They added that the common approaches to investment appraisal for building projects are the payback period and discounted cash flow (DCF) techniques. The payback approach is unable to capture the time value of money and the lifetime of the investment (Christersson, Vimpari, & Junnila 2015). The DCF techniques include the net present value (NPV), internal rate of return, return-on-investment, and benefit/cost ratio, (Tokede, Love and Ahiaga-Dagbui 2018). The NPV method is the most widely used generally accepted approach for investment appraisal (Akkoyun 2012; Ma et al. 2012; Kishk et al. 2003; Boussabaine & Kirkham 2004). However, these traditional methods of investment appraisal used in WLC are unable to take account of the value of operational flexibility of a project and uncertainties in costs and benefits (Trigeorgis 1996; Cruz & Sanchez 2017; Peters, 2016; Fawcett 2011). Therefore, the need for innovative approaches to overcome some of the limitations of the DCF techniques.

According to Tokede, Love and Ahiaga-Dagbui (2018), mathematical modelling has been used for WLC which builds on the NPV method and it provides a relevant framework to assess the investment potential of buildings. Many researches have been conducted under the standard WLC approach and different models have been developed. However, under the standard WLC approach, decisions are made "now or never". But, there is uncertainty in future costs, which include costs related to future changes to building uses, changes to resource consumption, and alterations to facilities throughout a building's life (Ashworth & Perera 2013). Although Kishk et al. (2003) argued that the principles of WLC are well developed in theory, Tokede Love and Ahiaga-Dagbui (2018) encapsulated that there is convincing evidence that this is not the case. They added that there is room for improvement on the weaknesses of the standard WLC approach, especially in emerging building typologies. This brought about the need for a new generation WLC (Ellingham & Fawcett 2006) which uses lifecycle options (LCO) – flexible strategies incorporated in the initial design of a building which allows for alternative courses of action to be followed in the future (Fawcett, Hughes & Ellingham 2012).

LCO is in line with real options (RO) approach (Ellingham & Fawcett 2006) which is also another popular investment valuation method (Peters 2016; Tokede, Love & Ahiaga-Dagbui 2018). According to Kodukula and Papudesu (2006), the RO approach addresses the weakness of the DCF techniques. Katerina (2015) added that the best way to value a development project is through RO valuation theory. When using the RO approach, it is important to anticipate future trends (Tokede, Love & Ahiaga-Dagbui 2018) which can be modelled using the binomial tree approach (Menassa, 2011; Neroutsou & Croxford 2016). Therefore, this approach can guide building investment decision-makers in making better decisions to increase whole-life value (Ellingham & Fawcett 2013). Lawal and Ibrahim (2018) identified the types of LCOs to include development or deferral option, expansion or upgrade option, abandonment option, switching use option, option for new technology, reconfiguration option, refurbishment option, contraction option,

option to suspend project, and option to switch projects. This paper proposes a model for the evaluation of expansion options (EO) in buildings.

According to Ellingham and Fawcett (2006), most buildings have EOs but some are not recognised and incorporated in the initial design. They added that identifying and creating EO in initial building design facilitates future expansion and thus making it more valuable. Also, Stephen et al. (2016) stated that although the initial cost is increased by creating EO, but the flexibility for future expansion will be improved. Therefore it is obvious that EO adds value to a building but, it is created for uncertain and distant benefits. Since, creating EO in initial building design requires additional investment and the future is unknown whether or not the option would ever be exercised, therefore, it is crucial to evaluate the option's value. Ellingham and Fawcett (2006) stated that though, EO is common, it is usually not evaluated and mostly overvalued or undervalued. They further stated that undervaluing EO happens when future expansion is made unnecessarily expensive or impossible because EO was not initially created or retained, while overvaluing EO happens when resources are committed for unlikely expansion possibility. Hence, this paper develops a model for the evaluation of EO in buildings. The objective of this paper is to present a model that quantifies the value of creating EO in initial building designs.

LITERATURE REVIEW

Expansion Option (EO)

EO comes into play where an investment permits the present capacity to be increased (Peters 2014) i.e. when a building is capable of being expanded (Ellingham & Fawcett 2006). According to Cruz and Sanchez (2017), EO offers the option of increasing the productive scale of a project by making additional investment. Sun, Wang and Meng (2019) added that EO is a type of real option, whereby an investor has the right, but not the obligation, to expand the project's scale as market conditions change. That is, a developer can invest further into a project if conditions are favourable. Other authors pointed out that EO is equivalent to an American call option, given that it allows for the consideration of making an additional investment if a project is profitable (Copeland, Koller & Murrin 2000; Peters 2016). Peters (2016) added that the exercise price of EO is equivalent to the cost of creating the additional space discounted to the time of the option exercise. Schwartz (2013) and Peters (2016) stated that an investor may even accept a negative NPV on the initial evaluation of a project because of the possibility of high positive NPVs in the future. Therefore, take account of future uncertainty, some developers build on a small scale, and in the future if there is positive growth in demand, the scale can be expanded. Panayi and Trigeorgis (1998) agree that this "wait and see" approach significantly improves the project's value. The major decision under EO is to determine the value of creating EO and the right time to exercise the option (Lawal 2020). Ellingham and Fawcett (2006), outlined five factors upon which EO depends. These are:

1. Amount of uncertainty: EO is more valuable when there is high uncertainty.
2. Duration of option: EOs that are longer lasting or perpetual are more valuable.
3. Trigger point: EOs are more valuable if the probability of exercising the option is high.

4. Cost of exercise: EO is more valuable if the cost of exercising the option is low.
5. Resulting benefit: EO is more valuable if the resulting benefit is high when the option is exercised.

Expansion Capacity (EC)

Expansion capacity involves the ability to increase facilities, space, or size over time to meet increased demand (Stephen et al. 2016). Stephen et al. (2016) added that the future expansion capability gives a building a real option that may be exercised at any time or never. The future demand determines the optimal time to exercise EO in the future. Stephen et al. (2016) suggested that EO should only be exercised when it has a positive NPV, as shown in Figure 1. This allows a developer to guard against the consequences of unfavourable circumstances and to benefit from the possible opportunities that may arise during implementation (Stephen et al. 2016).

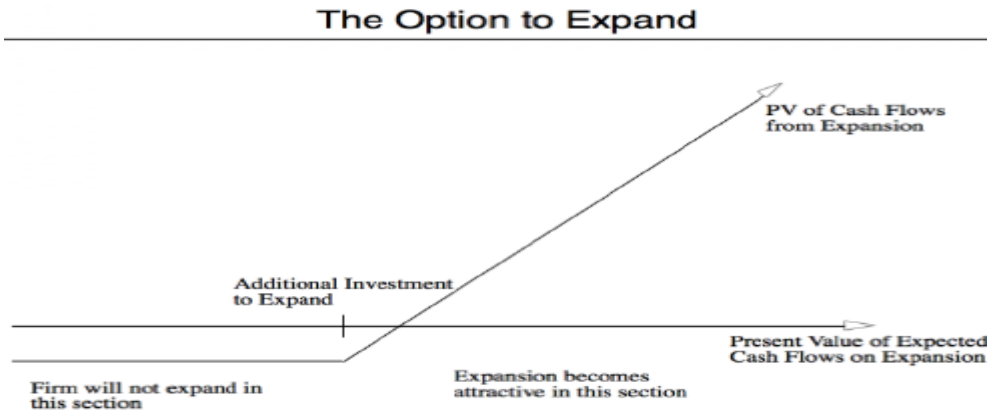


Figure 1: Positive NPV is needed to exercise expansion option (Source: Stephen et al. 2016).

Real Options (RO)

RO is the right but not the obligation to undertake certain business initiatives, such as developing, deferring, abandoning, expanding, staging, or contracting a capital investment project. Real options analysis (ROA) originated from financial options and gained popularity after the development of the Black-Scholes option-pricing model (Kwabena et al. 2018). The term "real option" was introduced by Myers (1977). Copeland and Antikarov (2001) refer that an option holder has the right but not the obligation to exercise an option until its expiration date. According to Peters (2016), the common types of real options are the option to defer, option to expand or contract and option to abandon or switch. According to Peters (2016), the fundamental methods for ROA are the Black Scholes method (BSM) and the binomial method (BM). Peters (2016) added that the other methods are either an extension of these two or simulation-based models.

Lifecycle Option (LCO)

The options approach to whole-life costing (WLC) was proposed by Ellingham and Fawcett (2006). The approach adopted the term 'lifecycle options 'which provides the basis for a new generation WLC. The principle behind LCO is that rather than making decisions today when there is high uncertainty, it would be better if decisions are made in the future when more information becomes available. Fawcett, Hughes, and Ellingham (2012) defined LCO as a design feature that is incorporated in the initial design and construction of a building, which allows for alternative courses of action to be followed in the future. LCOs are an instance of

the more general concept of RO and they provide opportunities to respond to future changes (Fawcett, Hughes & Ellingham 2012). These future changes can emerge from (Tokede, Love & Ahiaga-Dagbui 2018):

- Economic benefits: e.g. saving future costs of building maintenance.
- Technological benefits: e.g. harnessing new and evolving technologies such as smart meters and control.
- Social benefits: e.g. response to legislative changes – asbestos ban
- Environmental benefits: e.g. minimising the embodied energy in buildings.

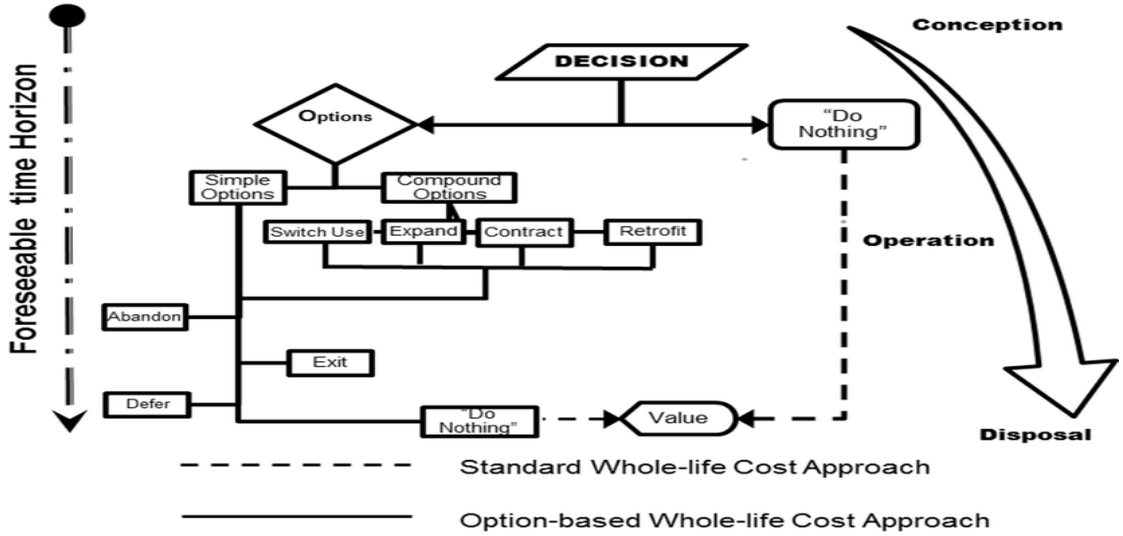


Figure 2: Mapping Whole-life Cost decisions in a Real-Options Framework (Source: Tokede, Love & Ahiaga-Dagbui 2018)

Figure 2 shows the decisions in the standard WLC approach and the options-based WLC approach. LCOs appraisal builds on scenario modelling and aims to foster the creation of options that ensembles optimal and long-term performances in buildings (Goh & Sun 2016).

Binomial Method (BM)

The BM was first proposed by Cox, Ross, and Rubinstein (1979) and provides a general method for options evaluation (Peters 2016). The BM is suitable for representing uncertainty that increases over time and it has the advantage of being easy to build and understand (Lawal et al. 2021). Though it is sometimes computationally stressful, but it can be successfully implemented on a spreadsheet package. According to Mun (2002), although both BM and BSM are proven to provide reliable results, BSM has limitations of being very difficult to derive and highly specific (Mun 2002). Mun (2002), pointed out that the BM is easy to implement and explain because it requires no more than simple algebra.

Monte Carlo Simulation (MCS)

Computer simulation can be used when there are uncertainties in input variables. MCS is a widely recognized tool that was introduced in capital budgeting problems by Hertz in 1968. According to Brealey, Meyers and Allen (2006), MCS can be used to generate all possible combinations of inputs and therefore, capable of generating the entire distribution of all possible outcomes. Loizou and French (2012) added that MCS assists decision-makers to be more rational and consistent

in their decisions and to gain a greater understanding of all of the risk factors in a development project.

Call and Put Options

Peters (2016) and Ellingham and Fawcett (2006) stated that there are two basic forms of financial options which can be grouped into call and put options. According to Arnold (2014), a call option gives the option holder the right (but not the obligation) to buy a stock at a particular price within a specified period while a put option gives the option holder the right (but not the obligation) to sell a stock at a particular price within a specified time. Hence, the put option can be viewed as the opposite of the call option (Lawal et al. 2021). Arnold (2014) posited that the exercise of an option prior to maturity can occur if the option is an American option whereas a European option can only be exercised at maturity. Peters 2016) added that for the American option, an option holder has the right to exercise the option at any time during its life while for the European option, the option holder has the right to exercise the option only at the end of its life.

METHODOLOGY

In this paper, an innovative model for the evaluation of EO in buildings has been developed to improve the economic sustainability of proposed building projects. Mathematical equations were developed based the on BM of real options analysis (ROA) first developed by Cox, Ross, and Rubinstein (1979). The mathematical equations were derived in line with ISO 15686-5 (Life-cycle costing) cost breakdown structure. Kirkham (2015), pointed out that ISO 15686-5 has addressed the issue of lack of standardization and lack of common cost breakdown structure in WLC. The mathematical equations were used to develop an algorithm for determining the value of creating EO in the initial building design. The algorithm was then implemented on a computer system using excel spreadsheet software. Besides, MSC was used to complement the BM which takes account of uncertainties in input variables. Another algorithm was also developed in form of a flow chart for the simulation which was also implemented on excel spreadsheet software. To ascertain the robustness and reliability of the model, real-life data was collected and used to test the model. Sensitivity analysis (SA) was conducted to explore the influence of the input variables on expansion option value (EOV). SA allows the evaluation of the relationship between different input variables and EOV and examines what can actually happen to a project in different situations (Brealey, Meyers, & Allen, 2006). SA is performed by changing some input parameters or one parameter at a time in a certain range while keeping other parameters unchanged and then calculates all the possible project values according to the changed parameters (Sattarnusart, 2012). This process will enable the project owner to identify all the key variables and to determine which input parameters are most likely to deviate from the estimated values (Sattarnusart, 2012). In this paper, SA was used to carry out a more in-depth analysis. However, the SA performed in this paper does not focus on determining the optimistic or pessimistic scenario of the project but rather, on studying how some of the input parameters affect EOV.

RESULTS AND DISCUSSION

Model Design and Development

The model was designed based on BM of ROA and in line with ISO 15686-5 (LCC) cost breakdown structure. The BM was tweaked to accommodate BEO. Besides, MCS was used to complement the BM.

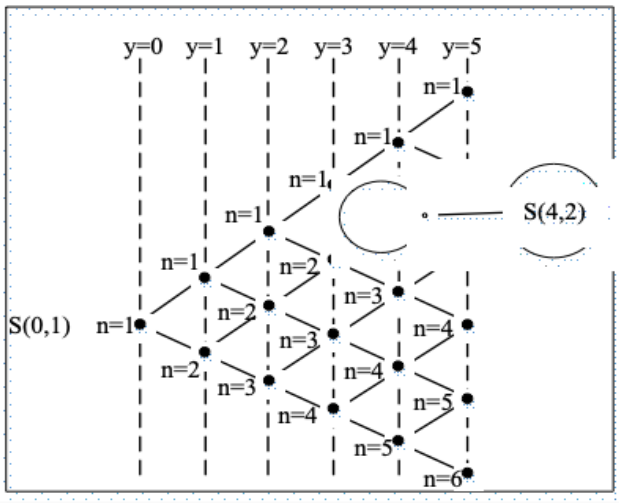


Figure 3: A Recombining Binomial Tree Showing Steps and States (Source: Lawal et al., 2021)

Figure 3 shows a five time-steps recombining binomial tree showing Steps (y) and States (n) as used in this work. Steps y represent the change in time on the binomial tree. The vertical dotted lines from 0 to 5 represent the steps (step 0, step 1, etc.). States n represents the number of nodes on each step. States (n) are represented numerically with numbers from top to bottom. All nodes on the binomial tree are represented as S (y, n). The highlighted node S (4, 2) is the node on step 4 and state 2. This applies to every node on the binomial tree.

Mathematical Equations

This work is in a series of research carried out by the authors. This paper builds upon a previous model developed for building development appraisal (Lawal et al. 2021). Thus, the following were adopted for this work.

Equation [1] is used for computing Future Values (FV) on a binomial tree (Lawal et al. 2021):

$$FV_{(y,n)} = V_0 \times (1+\delta)^{y-(2n-2)} \quad \ldots\ldots\ldots\

Where; $PV_{(y,n)}$ = PV at the node being studied, $V_{(y,n)}$= The entry/value at node (y,n), P_u =Upward probability, P_d =Downward probability, r = Discount rate.

1. Development Option Value (DOV)

Equations [3], [4], and [5] can be used for determining net present value (NPV) of development and development option value (DOV) (Source: Lawal et al. 2021).

$$NPVd_{(y,n)} = LCBD_{(y,n)} - LCCD \quad [3]$$

$$DVv_{(y,n)} = Max\left[NPVd_{(y,n)}, 0\right] \quad [4]$$

$$DOV_{(y,n)} = Max\left[DVv_{(y,n)}, Vd_{(y,n)}\right] \quad [5]$$

Where: LCCD = Lifecycle Cost of Development, LCBD = Lifecycle Benefit of Development, DVc = Development Cost, NPVd = Net Present Value of development, $I_C = Initialcost, C_C = Constructioncost, N_C = Non-constructioncosts, O_C = Operatingcost, M_C = Maintenancecost, T_C = Terminalcost$, $DVv_{(y,n)} = DevelopmentValue$, DOV=Development Option Value

2. Expansion Option Value (EOV)

EOV is the savings made whenever the expansion work is carried out (Lawal 2020). Thus, the following equations were developed as follows:

- Cost of expansion without created option = Cost of creating the option at the time of expansion + Expansion cost.

Let, CEw = Cost of expansion without created option, Cw = cost of creating the option at the time of expansion, and Ec = Expansion cost. Thus;

$$CEw = Cw + Ec \quad [6]$$

- Cost of expansion with created option = Cost of creating the option in initial design + Expansion cost.

Let, CEo = Cost of expansion with a created option, Co = Cost of creating the option in the initial design, and Ec = Expansion cost. Thus;

$$CEo = Co + Ec \quad [7]$$

- Expansion saving = Cost of expansion without created option — Cost of expansion with created option.

Let, EOS = Expansion saving. Thus;

$$EOS = CEw - CEo \quad [8]$$

Using Equations [6], [7] and [8];

EOS = (Cw + Ec) — (Co + Ec)

EOS = Cw + Ec — Ec — Co

Thus;

$$EOS = Cw - Co \quad [9]$$

Therefore, EOS is the difference between the cost of creating EO at the time of expansion and the cost of creating EO in the initial design.

Equation [9] can be modified to suit Figure 3 as used in this work. This yields Equation [10]:

$$EOS_{(y,n)} = \left[Cz_{(y,n)} - Co\right] \quad [10]$$

Also, let, EVw = value of expansion without created option, EVo = value of expansion with created option, EOV(y,n) = value of creating EO in initial design, LCBD = lifecycle benefit of development and LCCD = lifecycle cost of development. From a whole-life perspective, EVw and EVo can be represented as follows:

$$EVw = LCBD_{(y,n)} - [LCCD + CEw] \quad [11]$$

$$EVo = LCBD_{(y,n)} - [LCCD + CEo] \quad [12]$$

Thus, EOS in terms of the lifecycle benefits and costs can be represented in Equation [13]:

$$EOS_{(y,n)} = Max\left[EVw_{(y,n)} - EVo_{(y,n)}, 0\right] \quad [13]$$

The value of creating an expansion option in the initial design ($EOV_{(y,n)}$), is the backward discounting of all values on $EOS_{(y,n)}$ binomial tree. This is the cumulative weighted average of all entries on the $EOS_{(y,n)}$ binomial tree. Therefore, let $V^{e}_{(y,n)}$ be the cumulative weighted average of all entries on the $EOS_{(y,n)}$ binomial tree. Using Equation [2] the value of creating EO in the initial design can be represented in Equation [14]:

$$V^{e}_{(y,n)} = V_{(y,n)} + \left[P_u \times \frac{V_{(y+1,n)}}{(1+r)}\right] + \left[P_d \times \frac{V_{(y+1),(n+1)}}{(1+r)}\right] \quad [14]$$

Since we are concerned with only positive NPVs, all negative values are replaced with zeros. Thus, expansion option value, EOV can be as follows:

$$EOV_{(y,n)} = Max\left[V^{e}_{(y,n)}, 0\right] \quad [15]$$

Model Algorithm

An algorithm was developed for computing the value of creating EO in the initial design. The algorithm was formulated into modules to make it more comprehensive. Figure 4 shows the algorithm for determining the value of creating EO in the initial building design. The modules are presented in Figures 4.1 to 4.15 in the Appendix.

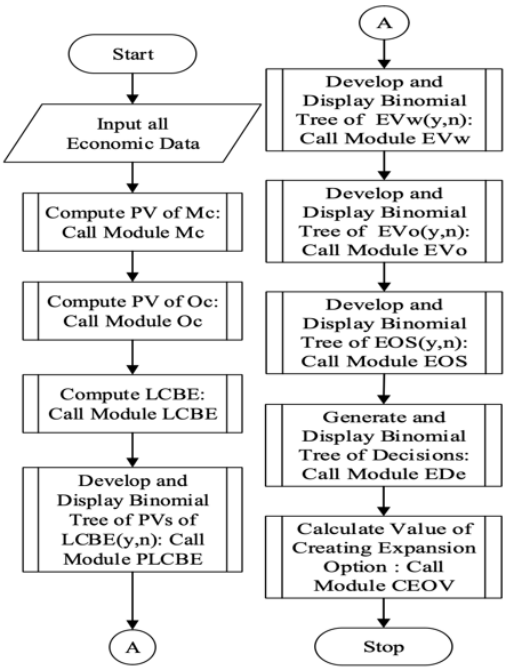


Figure 4: Algorithm for determining the value of creating EO

Model implementation

The model was implemented on a computer system. Microsoft Excel Spreadsheet Software was used for the implementation of the model with the aid of the formulated algorithms.

Model evaluation and testing

A proposed building project was used to test the reliability and validity of the model. The project has an approximate land area of 1,207.8m2 and an overall building area of 529.60m2. An EO was created in the project. The EO is the option to expand the building by creating an additional floor. The following data was obtained and used in the model:

Construction Cost -	**₦34,424,000**	Volatility-	**11.4%**
Non Construction Cost-	**₦8,850,000**	Time Steps-	**1**
Maintenance Cost-	**₦6,884,800**	Borrowing Rate-	**11.75%**
Operating Cost-	**₦504,455/year**	Inflation Rate-	**11.25%**
Expected Benefits-	**₦1,600,000/year**	Terminal Cost-	**₦1,988,800**
Residual Value-	**₦8,690,000**	Analysis Period-	**30years**
Cost of creating EO in initial design-			**₦11,782,200.00**
Cost of creating EO at time of expansion-			**₦15,972,200.00**
Cost incurred due to non-creation of option-			**₦1,000,000.00**
At least 1 year of rental income to be lost-			**₦1,600,000.00**
Repair costs after creating option at the time of expansion-			**₦1,500,000.00**
Substructure-			**₦9,084,500.00**
Superstructure-			**₦25,339,500.00**
Roof-			**₦6,282,400.00**
Rental Value/ annum-			**₦1,600,000.00**

The development option value (DOV) model was used to determine the lifecycle benefit of expansion. From the results, the model suggests that EO should be created in the initial design. The value of creating EO in the initial building design over 30 years is 2.05 million. All through the option validity period, the value of creating EO in the initial design is positive meaning that EO should be created.

Table 1: Value of creating EO in the initial design

Yr	EVw (M ₦)	EVo (M ₦)	EOV (M ₦)	Yr	EVw (M ₦)	EVo (M ₦)	EOV (M ₦)	Yr	EVw (M ₦)	EVo (M ₦)	EOV (M ₦)
0	3.82	7.92	4.10								
1	5.06	8.20	3.15	11	11.64	14.07	2.43	21	16.00	18.21	2.21
2	6.17	9.21	3.05	12	12.21	14.59	2.38	22	16.45	18.62	2.18
3	6.86	9.71	2.84	13	12.60	14.97	2.37	23	16.78	18.95	2.17
4	7.72	10.49	2.77	14	13.13	15.46	2.33	24	17.21	19.35	2.13
5	8.28	10.96	2.68	15	13.51	15.83	2.32	25	17.53	19.67	2.14
6	9.02	11.64	2.62	16	14.02	16.30	2.29	26	17.95	20.06	2.11
7	9.51	12.08	2.57	17	14.37	16.65	2.28	27	18.25	20.37	2.10
8	10.17	12.69	2.52	18	14.86	17.10	2.25	28	18.67	20.74	2.08
9	10.62	13.11	2.49	19	15.20	17.44	2.24	29	18.97	21.05	2.07
10	11.23	13.67	2.44	20	15.67	17.87	2.20	30	19.37	21.42	2.05

Table 1 shows the results for the value of creating EO in the initial building design. The value of creating EO is higher in the early years and slightly reduces towards the latter years of a building. This agrees with Ellingham and Fawcett (2006), who concluded that EO depends on the duration of the option (longer-lasting options are more valuable). Also, the result shows that EVo (value of design with EO) is ₦ 21,415,951 and EVw is ₦ 19,365,116 (value of design without EO). This shows that the value of creating EO in the initial design is ₦ 2,050,835 (the difference between EVo and EVw). Therefore, EO creates an increase in the value of the building by about 10.6%. This indicates that creating EO in the initial design is very valuable because it adds over 10% value to a building project.

Sensitivity Analysis (SA)

The SA performed in this paper does not focus on determining the optimistic or pessimistic scenario of the project, but rather on studying how some of the input variables affect expansion option value (EOV). The uncontrollable variables were changed to examine their effect on EOV. This was done by changing one variable at a time and fixing the others. All input parameters were fixed according to the base parameters in the project. From all the analyses, the effect of changing different variables on EOV can be summarized in Table 3.

Table 2: Summary of the SA

Input Parameters	EOV
Rental Value	+
Volatility	+
Borrowing Rate	—
Inflation Rate	+
Discount Rate	—

As shown in Table 2, an increase in rental value (Ri) positively affects the option value. This agrees with Ellingham and Fawcett (2006), who stated that EO is more valuable when there are higher benefits. An increase in Ri by just 5% causes a corresponding increase in option value by 10.60%. Also, an increase in volatility (δ) creates a positive change in option value. This is also in agreement with Ellingham and Fawcett (2006), who concluded that EO is more valuable when there is more uncertainty. An increase in δ by 5% causes a corresponding increase in value by 5.85%. However, the increase in EVw and EVo is the same (5.85% increase) which means their difference (EOV) remains constant. This means that an increase in δ creates an equal and positive increase in both EVw and EVo with constant EOV. Moreover, an increase in borrowing rate (b) has a negative effect on the option value. Since an increase in b will result in a higher cost of exercising EO, this also agrees with Ellingham and Fawcett (2006), who concluded that EO is less valuable if there is a high cost of exercising the option. An increase in b by just 5% causes a corresponding decrease in option value by 14.61%. More so, an increase in the inflation rate (i) has a positive effect on EOV. Since an increase in i will result in higher expected benefits, this also agrees with Ellingham and Fawcett (2006), who concluded that EO is more valuable if there are large benefits. An increase in i by just 5% causes a corresponding increase in the option value by 16.26%. Lastly, an increase in the discount rate (r) has a negative effect on the option value. An increase in r by 5% causes a corresponding decrease in the option value by 6.9%. Therefore, when evaluating EO in initial building designs, there are many variables as the inputs and inflation rate (i), borrowing rate (b), and rental value (Ri) are the most significant variables. This implies that building investment decision-makers should carefully determine all the input parameters, especially the ones related to i, b, and Ri to have a reliable result.

Simulation

To determine the expected EOV and all possible EOVs, a Monte Carlo simulation was used. The objective of the simulation is to find the expected EOV and all possible EOVs.

Simulation design

The design of the simulation follows the following steps:

1. Use the base values in the EOV model
2. Randomly select values for Rental Value (Ri), Volatility (δ), Borrowing Rate (b), and Inflation Rate (i)
3. Calculate EOV
4. Repeat until 10,000 iterations are reached
5. Use the values to produce a frequency curve
6. Identify the most likely EOV

The procedure of running the simulation can be described by the flow chart in Figure 5. MS Excel was used to run the simulation with the aid of the algorithm.

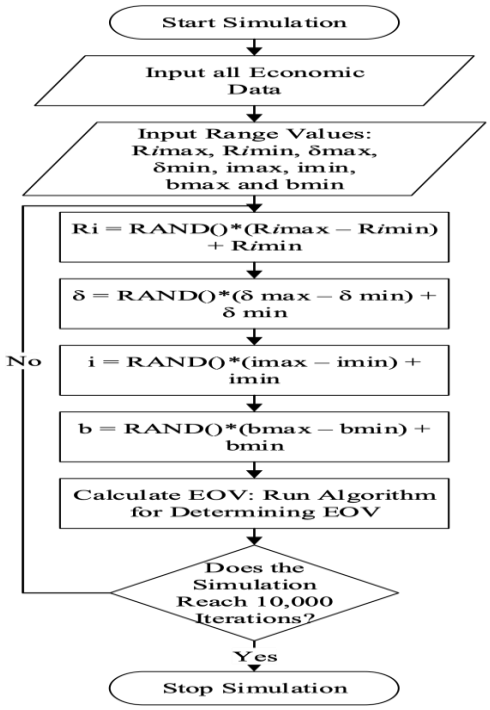


Figure 5: Flow Chart of EOV Simulation

Simulation result and analysis – EO creation value

The possible values of EOV are plotted to examine the distribution of the results and the key statistical measurements are calculated for the analysis of the results. Figure 6 shows the distribution of all possible EOVs.

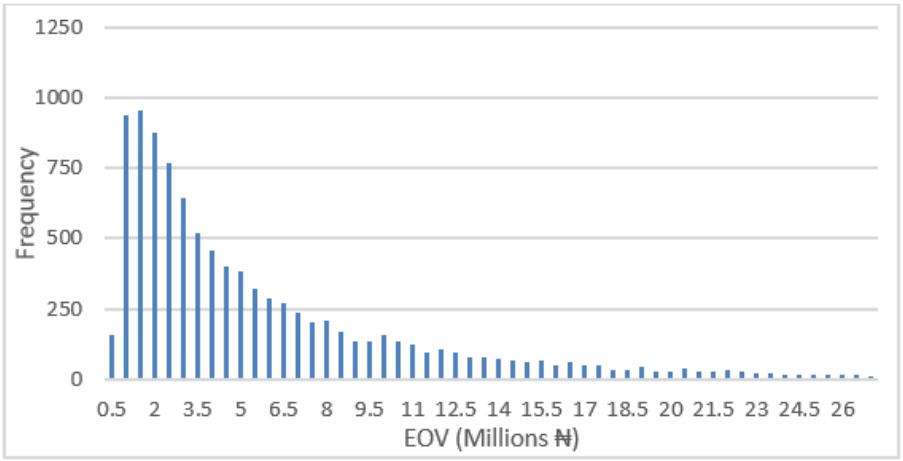


Figure 6: Distribution of Possible EOVs (EO Creation Value)

Table 3 shows the statistical results (EO Creation Value):

Table 3: Statistical Measurement of EOV Simulation (EO Creation Value)

Statistical Measurement	Value
Maximum	**38,791,649.01**
Minimum	**336,412.30**
Standard Deviation	**6,180,714.34**
Average	**5,948,189.92**
Skewness	**1.97**
Kurtosis	**4.17**

The result shows that the most likely EOV is ₦5,948,189.92. However, the EOV obtained using only the BM is ₦2,050,385.00. This shows that by incorporating MCS into the analysis, EOV increases by 190%. This difference has to do with the ability of the MCS method to take account of uncertainty in input variables. MCS method can generate all possible combinations of input variables. As such, the MCS method should be used to complement the BM for more reliable results. Also, from the result, the maximum EOV happens to be ₦38,791,649.01 while the minimum EOV is ₦336,412.30. This provides the best-case and worst-case scenarios. The model suggests that EO should be created in the initial design. The result from simulation suggests a higher value than that derived from the binomial model only. As such, there is the need to use both the BM and MCS together to make reliable and sustainable building investment decisions. This paper has proposed an innovative model capable of determining the value of creating EO in initial building design.

However, the major decision under EO is to determine the value of creating EO in the initial design and the optimal time to exercise the option. Therefore, there is a need to further expand the model to capture the value of exercising EO. Further research is ongoing which is aimed at expanding the model to be capable of predicting the most likely viable times over which EO could be triggered without affecting the value of a building project. After completing the research, the model should be capable of predicting the right times to exercise EO over a building's lifecycle. More so, to predict the optimal time of expansion, there is the need to generally improve the model using artificial intelligence (AI). With high uncertainty on the nature and times of possible future expansion, it is a difficult task to predict the optimal time of expansion. As such, there is the need to improve the model using AI-based algorithms.

CONCLUSIONS

This paper proposes an innovative model for evaluating EO in buildings. The model, which is based on the BM of ROA, takes account of managerial flexibility and volatility in costs and benefits over the lifecycle of a building. The model is capable of determining the value of creating EO in initial building designs. The study concluded that inflation rate (i), borrowing rate (b), and rental value (Ri) are the most sensitive variables for EOV as an increase in i and Ri by just 5% causes a corresponding increase in EOV by 16.26% and 10.60% respectively. While, an increase in b by just 5% causes a decrease in EOV by 14.61%. However, the least sensitive variables appear to be the discount rate (r) and volatility (δ) as an increase in r by 5% causes a decrease in EOV by 6.9% while an increase in δ causes an increase in option value by 5.85%. More so, creating EO in initial building design is very valuable because it adds over 10% value to a building project. Moreover, by integrating MCS and BM, EOV increases by 190%. The study recommends that building investment decision-makers should use both the BM and MCS methods together for reliable and sustainable decisions. Further research is required to expand the model to be capable of predicting the right times to exercise EO. In addition, the model needs to be improved by using machine learning algorithms.

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APPENDIX

Modules

Figures 4.1 to 4.9 are the modules as used in the Algorithm.

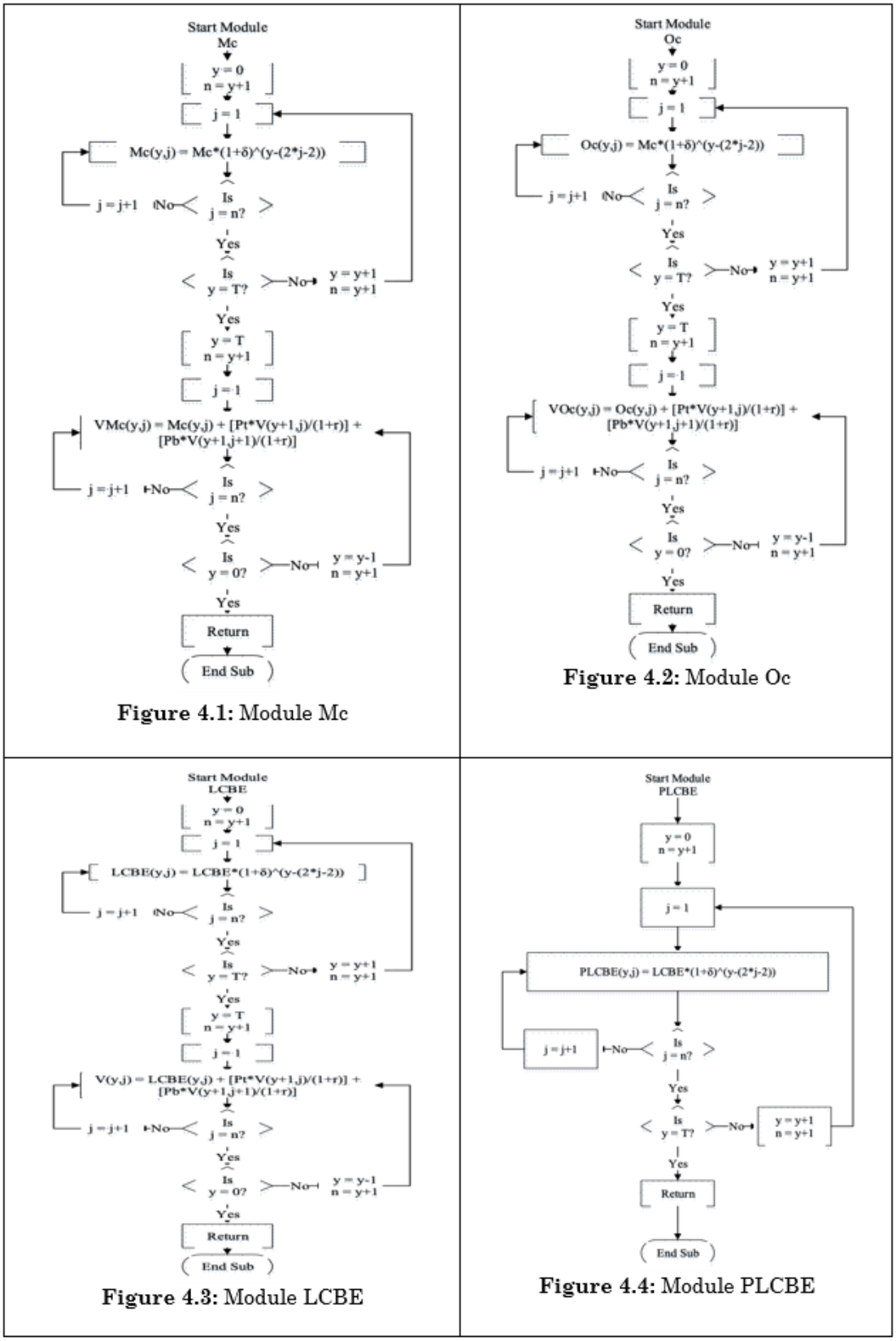


Figure 4.1: Module Mc

Figure 4.2: Module Oc

Figure 4.3: Module LCBE

Figure 4.4: Module PLCBE

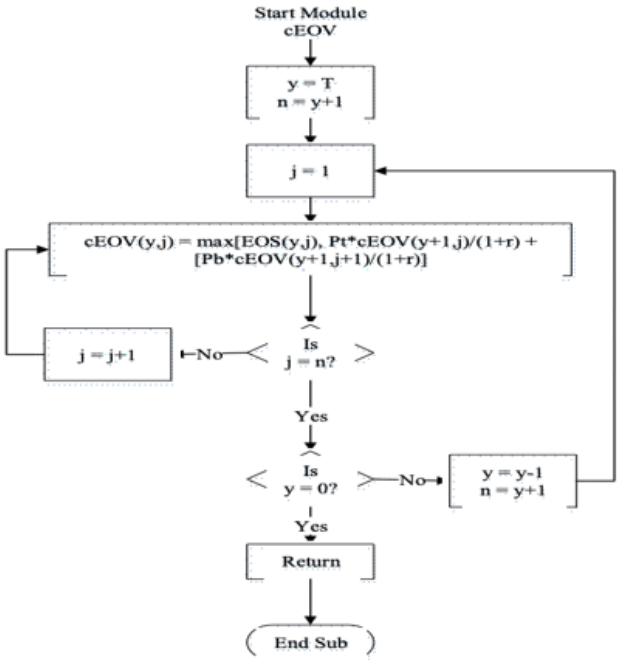


Figure 4.9: Module CEOV